A Mind-Controlled Low-Cost Sensorised Modular Hand

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INTRODUCTION

Modular grasping makes it possible to use only the necessary number of DOFs to accomplish a specific grasp. As such, a trade-off between simple grippers and more complex human like manipulators can be reached [1].

From a biological point of view, one of the most attractive challenge, when building robotic hands, consists of realising a transparent and reliable control interface for the user. A control solution that offers a biologically transparent integration consists of using the user's neural oscillations as inputs to control the hand.

To explore this possibility, a mind-controlled three-fingered modular manipulator is presented in this work. The hand is designed and developed with ModGrasp [2], an open-source virtual and physical rapid-prototyping framework that allows for the design, simulation and control of low-cost sensorised modular hands. In particular, an electroencephalography (EEG) headset, the NeuroSky MindWave, is adopted to monitor the user's levels of attention and meditation. These levels are used as inputs to control the hand. Since the manipulator features 11 DOFs, a synergistic control approach is chosen to map inputs with outputs with such a different dimensionality.

The idea is shown in Fig. 1.

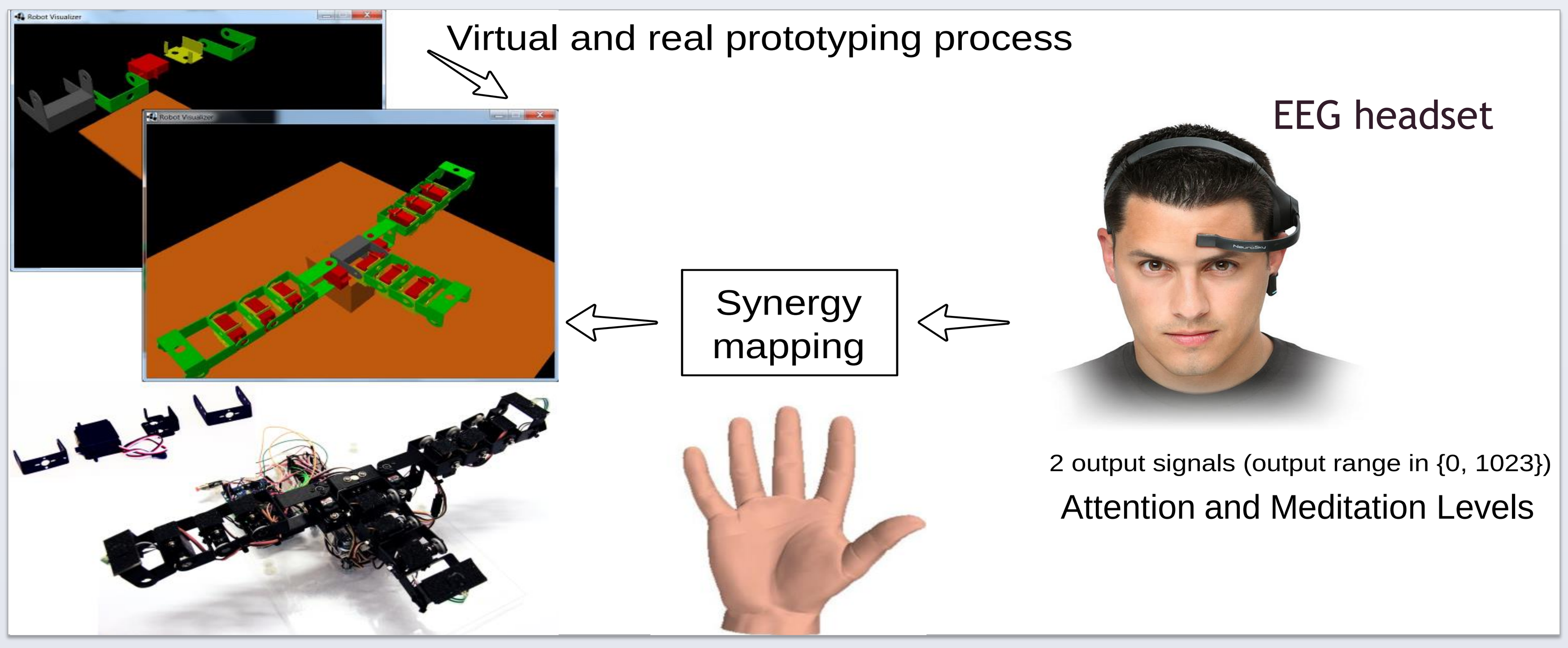

Fig. 1 The idea of realising a mind-controlled low-cost sensorised modular hand.

ARCHITECTURE AND CONTROL APPROACH

The fundamental module of the hand is made by a standard micro servo motor and two metal brackets. Each module can be connected to another one in a pitch-pitch or in a pitch-yaw connection configuration. Two special brackets allow for abduction/adduction and flexion/extension movements respectively.

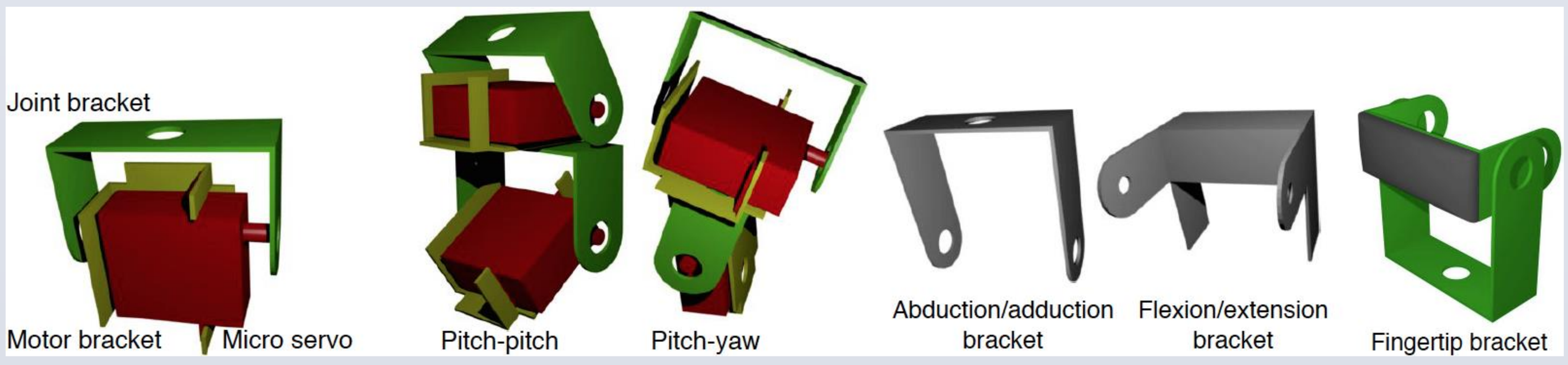

Fig. 2 The fundamental building module of the hand.

The hand consists of one finger having 3 DOFs (the thumb) opposing the two other fingers with 4 DOFs each. The concept of modularity is also applied to the system architecture on both the software and hardware sides. In particular, as shown in Fig. 2, a master-slave communication pattern is used. Each finger is controlled by a slave controller board, which communicates with a master controller board.

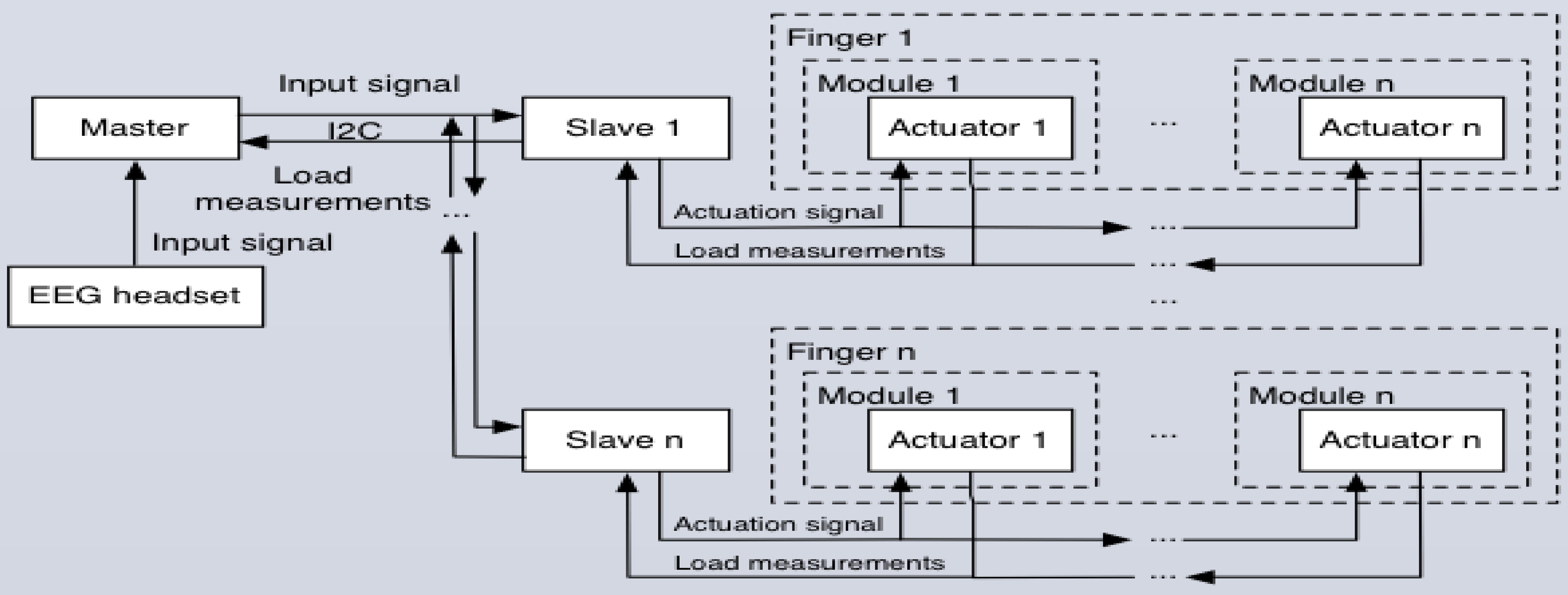

Fig. 2 The system architecture: a master-slave modular pattern is used for the communication protocol.

Since the hand features 11 DOFs, a synergistic control approach is chosen to simplify the control algorithm [3]. In particular, let the manipulator be described by the joint variable vector $q_h \in \Re^{n_{qh}}$, with n_{qh} representing the number of actuated joints. We assume that the subspace of all configurations can be represented by an input vector of a lower dimension $z \in \Re^{n_z}$(with n_z denoting the number of inputs and $n_z \leq n_{qh}$) which parameterises the motion of the joint variables along the synergies. In terms of velocities, one gets:

$$\dot{q} = S_h \dot{z}$$

being $S_h \in \Re^{n_{qh} \times n_z}$the synergy matrix.

In order to monitor the load of each joint actuator, the current is continuously measured from each slave controller. In particular, the current sensing at the joints level allows for a more accurate grasping of objects with different stiffness without squeesing or damaging them. By measuring the input current to each servo motor, the servo torque can be calculated and adjusted according to the task to be performed. Moreover, crucial functions like sensitive collision detection and compliant control actions are possible.

SIMULATIONS AND EXPERIMENTAL RESULTS

A set of daily objects which consists of a cube, a cylinder and a balloon, is selected for use in performing some grasp and release experiments. Special emphasis should be placed on the balloon grasp, shown in Fig. 3, because this task is particularly challenging. With this experiment, the hand demonstrates effectiveness in grasping objects with different stiffness without squeesing or damaging them.

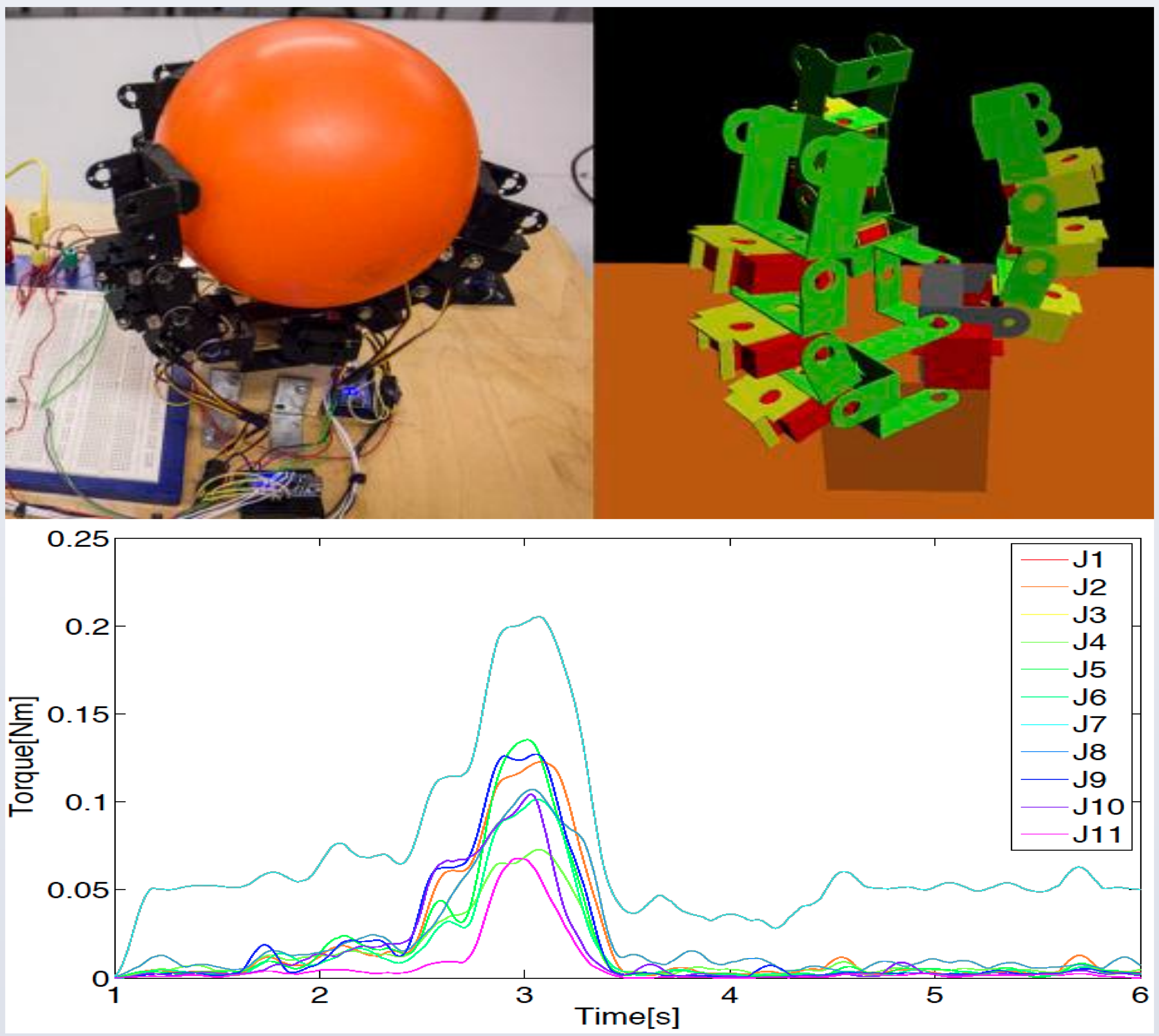

Fig. 3 The mind-controlled low-cost sensorised modular hand performing a balloon grasp.

CONCLUSIONS

This work highlights the potential of the modular grasping approach and it shows that a transparent control interface between the user and the manipulator can be achieved by only monitoring the user's neural oscillations by means of a low-cost EEG headset. To improve the system usability, in the future, a low-pass filter can be applied to reduce the noise from the collected data that come from the EEG headset.

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